

Developing and Evaluating an Open-Source GIS/Project Management Web Application

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Abstract

This case study explores web-based Geographic Information Systems (GIS) and how it contributes to the field of Project Management (PM), specifically an open-source GIS web solution. There are a number of different tools and techniques currently available to plan, design, and manage projects. In most cases, project managers must use a number of different software packages to complete a successful project. With the advent of application programming interfaces (API) and open-source software, proper cost effective tools can be at the disposal of project managers and staff. An open-source alternative exists on all levels of web GIS infrastructure. Project risk and waste can be limited with the ability to effectively plan and control projects, thereby increasing the probability of success. The website created in this case study provides users the ability to view the progress of a project - according to user needs. Its dashboard-style interface aids in visualizing and disseminating project information. A pilot-type PM GIS web application was created and evaluated using a User Experience Analysis survey. Survey results provided insight to end user needs and preferences, which will be utilized for future application development. By utilizing open-source resources, web GIS PM software is capable of rapid implementation with minimal input costs. With projects involving geography, a GIS is a natural tool to facilitate planning and monitoring throughout the life of the project.

Introduction

According to Reid and Martin (2001), open-source software can be used in implementing spatial data infrastructures. Open-source software allows resource-poor organizations to utilize application components, which are already developed and available. In most system designs, open-source construction provides feature-rich alternatives to proprietary software packages (Steiniger and Bocher, 2008). Even capital rich international information technology firms have adopted open-source software. Both IBM and Apple are utilizing open-source products in their

software architectures (West, 2007). The quality of many of these projects rivals their proprietary counterpart.

There are a number of different tools and techniques currently available to plan, design, and manage projects. In most cases, project managers must use a number of different software packages to complete a successful project. An open-source software option is available for each level of a web GIS infrastructure. By utilizing open-source resources, a web-based GIS Project Management (PM) application can provide effective tools with no software input costs. Project stakeholders all benefit from inexpensive value adding tools.

According to PMBOK (2004), project management is the application of knowledge, skills, tools and techniques to plan activities to meet project requirements. Projects have defined scope, schedule, and budget. Information systems have been used to help in all three of these project constraints. Being able to use traditional PM tools such as Critical Path Method and resource charts, improves the toolbox of the project manager. Adding the capability to visualize activities and their progress is an added benefit to the user. The pressure faced by project managers to shorten delivery times of complex projects has led to an increased number of commercially available computerized planning and scheduling tools, but the tools currently in use are in need of improvement.

Bansal and Pal (2008) make the case a GIS based approach provides both visualization and project management tools. Yi, Hoskins, Hillringhouse, Sorensen, Oberle, Fuller, and Wallace (2008) affirm the critical importance of timely information for monitoring and measuring progress; they conclude an open-source framework could provide public health officials a dashboard interface which would contribute to apt response times to critical situations.

One of the significant powers of GIS is the ability to publish spatial data over the internet for retrieval by multiple users. Sharing information over the internet allows dynamic data to be updated and disseminated. This promotes accessibility and timely, current information (Boulos and Honda, 2006). Vatsavai, Shekhar, Burk, and Lime (2006) also affirm many GIS applications require timely data which a web GIS platform provides. Because the internet provides efficient information distribution, GIS developers have means to electronically

deliver results to users broadly and quickly. Boulos and Honda add another benefit of distributing information using an internet web application; compared to a static paper map, web interaction provides options, which allow the users to define which layers of data are shown, thus suiting data display to their requirements.

Data-rich resources are available through the internet which can provide developers the ability to freely access code and data. Interoperability and information-sharing on the internet is commonly referred to as the Web 2.0. This new approach has tools such as application programming interfaces (API). Web 2.0 and open-source software are both quickly emerging, fueled by new technologies and mindsets on application development. The Web 2.0 service model provides developers the data and computing power of large companies, such as Amazon and Google, essentially for free (Floyd, Jones, Rathi, and Twidale, 2007). APIs allow developers to use components of existing, freely-available applications from multiple sources and then combine them into a single integrated web application (Yi et al., 2008). Yi et al. used Google Map as their mapping platform due to: API ease of use and implication, mainly coded in JavaScript, and robust developer support. In addition, nearly all web browsers are able to read it. According to Floyd et al., the primary obstacle with web GIS interoperability is defining standards necessary for functional integration. Efforts by the Open Geospatial Consortium provide recognized standards to alleviate these issues.

Vatsavai et al. (2006) conclude the readily available internet is changing the way spatial information is being disseminated. Medagama, Gamage, Wijesinghe, Leelaratna, Karunaratne, and Dias (2008) used an open-source web-

based mapping application to track the organization's vehicle locations in the field. They provide an example of efficiently and effectively managing resources using several modern information and communication technologies. These methods include modules to manage: resources, efficient routing, and operation reports.

This capstone project covers two goals: 1) design and build an open-source web-based GIS PM tool using software prototyping, 2) conduct a User Experience Analysis survey to access and evaluate the web application for future enhancement and development needs.

Methods

Data Preparation

A sample (dummy) project was created as the sample dataset which was used to source the web application. This sample project was created with a geographic influence. For the purpose of this case study, Hennepin County, MN, USA was selected as the scope of the sample project area. As for any project, planning is necessary to successfully fulfill project requirements. To breakdown the scope of the project, a U.S. Census Bureau 2000 "incorporated place" shapefile was used. The incorporated place spatial input is a geographic boundary file which contains (with a few exceptions in the eastern U.S.) cities, boroughs, towns, and villages of the United States. A county shapefile was used to clip the incorporated places shapefile to only include the geographic area of Hennepin County. The cities within Hennepin County serve as individual tasks within the schedule. Task duration is important to estimate. The area in square miles of each incorporated place (referred hereafter as "task") was

multiplied by 1.5 to determine the number of days needed to complete each task.

The mock delivery date is eight months away. To accomplish data collection in time, five resources were allocated. Once this was determined, using the open-source desktop MapWindowGIS, these five resources were assigned tasks in five subsections. The sequence of the task was based on the basic rule of thumb: concentrate on the longest tasks in the schedule first (Figure 1).

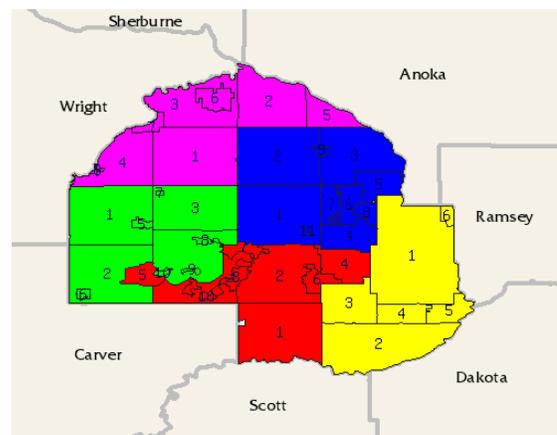


Figure 1. Mapserver image rendering the resource allocation. Each resource's tasks (cities) are coded into its own color. Numbers represent scheduled task sequence.

The schedule was designed with the Critical Path Method in mind. The Critical Path Method (CPM) is a schedule analysis tool that calculates theoretical early and late start/finish dates for activities and the minimum total project duration (PMBOK, 2004). Buell (2008) explains CPM is one of the standard tools used for scheduling and progress analysis. The incorporated place DBF was imported into Microsoft Excel and date functions were used to define estimated start and end dates for each task.

This sample project dataset was used as a pilot project, which users will be asked a series of questions to evaluate the applications pros and cons. The project

dataset focuses on two vital components of PM: project schedule and project resources. The incorporated place shapefile and the schedule were joined and then imported into an open-source database PostgreSQL.

Software Components

Database

The goal is to produce a solution which is open-source, web-based, and scalable. A number of components were needed. The foundation of an information system is the database. This component stores, organizes, and returns project information: tasks, resources, progress, and statistics to the web application.

PostgreSQL with PostGIS and MySQL with its Spatial Extension are the two main robust open-source databases that support geographic objects such as coordinate systems, projections, and geographic functions. PostgreSQL, commonly referred to as Postgres, was chosen due to its speed, high level of data integrity, spatial functionality, and large active user group. The default PostgreSQL installation cannot support operations on spatial data. An extension called PostGIS provides the added functionality to handle spatial queries and operations.

Mapping Server

An essential element to a web GIS application is the map. Mapserver is a full featured internet mapping server. This cross-platform mapping software has been developing alongside the surging open-source spatially-enabled internet applications. Although the original Mapserver was created before the Open Geospatial Consortium specifications were published, its continual project

improvement incorporates the latest in open-source GIS standards. The Open Geospatial Consortium (OGC) is one of the contributing causes for this maturity. Since OGC founding in 1994, Han, Di, Zhao, and Li (2009) reported, it has led development and distribution of standards relating to geospatial standards for framework and services. Both open-source and the web GIS community are utilizing the OGC standards (Steiniger and Bocher, 2008). Commercial entities producing proprietary software are implementing these standards also. Commercial software companies like ESRI, Geosystems, and Intergraph are actively supporting OGC standards. Through the sustained work of project members, Mapserver has become a Swiss Army Knife known worldwide and is chosen time and time again as the web solutions map service.

Development Platform

The web development was performed with Microsoft's Visual Web Developer Express 2010. This powerful web development environment uses the ASP.NET framework. Unlike the Visual Studio high-end product line, Visual Web Developer Express (VWDE) has no licensing restrictions. This free, powerful web designing environment licensing allows for commercial use. The Express version of Visual Web Developer is stripped down when compared to the other, more full-featured Visual Studio products, but the Express version is more than sufficient for the needs of this project. A few valuable features of this internet development environment are: IntelliSense provides fast access to methods and libraries, a great debugger, and programming server side code in VB.net.

Within the ASP.NET environment, three added open-source programming

libraries were used to read the application's PostgreSQL database and add functionality to the end user. To gain access to PostgreSQL, Npgsql 2.0.9 was used. Npgsql is an open-source ASP.NET data provider that interfaces with PostgreSQL database server. JavaScript was used through the jQuery library and Ajax Control Toolkit for Visual Studio was used to add specialty web components not provided in VWDE.

Internet Information Services (IIS), formerly known as Internet Information Server is the default ASP.NET Hyper Text Transfer Protocol (HTTP) server. To prevent the need for two servers, IIS and Apache, and to retain the open-source theme, Mod_AspDotNet was implemented to serve .NET through Apache. The Apache module is a freely downloadable solution developed to a point that only an install and some provided lines of code are needed for this bypass.

The Build

The GIS web application development was performed in four stages: 1) Mapserver and Apache Web Server installation and testing, 2) PostgreSQL and PostGIS installation configuration, 3) Creating the mapfile Layers to read PostGIS tables and creating the different user map views using thematic map expressions, and 4) Creating the application website using ASP.NET which interacts with Mapserver and PostgreSQL for its data sources.

Mapserver/Apache

The download manager OSGeo4W was used to obtain the necessary open-source applications and libraries for a web mapping environment. The OSGeo4W is an Open Source Geospatial Foundation project, and is a useful way to download

and update a wide array of geographic themed projects, including: GDAL/OGR, Proj.4, GRASS, Mapserver, OpenEV, uDig, and QGIS. OSGeo4W also includes the installation of Apache web server, which Mapserver uses for communication. Once this installation was complete and running, a simple command was sent by Microsoft's Internet Explorer and Mozilla Firefox internet browsers to ensure Mapserver and Apache were functioning correctly.

After Mapserver and Apache were tested and verified, it was time to produce a map output. Mapserver has the capability to generate Web Feature Service (WFS), Web Coverage Service (WCS), and Web Mapping Services (WMS). Although WFS would have more feature specific capability, such as advanced abilities: create, update, delete, and lock operations (Aydin, Sayar, Gadgil, Aktas, Fox, Ko, Bulut, and Pierce, 2008), for the purpose of this web GIS project a WMS was used. WMS is one of OGC defined standards that is commonly used. Han et al., (2009) explains WMS returns a static map when a client makes a request. Any standard client web browser can invoke a WMS compliant server for the services functions. These requests to the server are submitted as Uniform Resource Locators (URLs). The requests are processed on the server and the result (image) is passed back to the client.

Mapserver can act as a server and a client. As previously mentioned, Mapserver is capable of reading a variety of different inputs. These data inputs are referenced as Layers within the Mapserver Mapfile. A source for one of these mapfile layers can be generated using a web service, in essence causing Mapserver to act as a client before it serves it again. To add functionality allowing the user to monitor precipitation in a given project

area, the NEXRAD Base Reflectivity raster was retrieved from the Iowa Environmental Mesonet (IEM) as a WMS (Figure 2). This IEM NEXRAD raster request required parameters passed by URL. These included: layer type (nexrad), geographic extent (lat,lon), date/time, and image pixel dimensions (800x600).

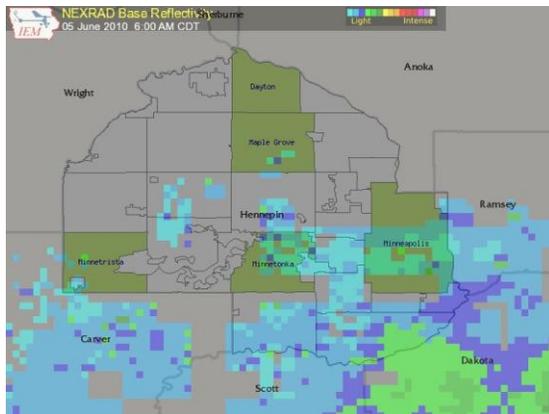


Figure 2. Mapserver produced image displaying the active tasks (green) and remote WMS precipitation raster service. This raster layer is being rendered partially transparent so it could be use as a layer overlay.

Postgres/PostGIS

The next step was importing the project data into PostgreSQL. The database created for this project was called, “ProjectDatabase”. It was designed to house two tables, one containing the tasks and schedule and the second dedicated to the resources which will perform the tasks. Since schedule information was added to the incorporated places shapefile and the resource table was generated using shapefiles, the PostGIS utility “Shape file to PostGIS Importer” was used to import these two inputs to the PostgreSQL “ProjectDatabase” database.

At this point, PostgreSQL contained the necessary data. The mapfile then required alterations to read the PostGIS data source. This was accomplished by adding three map objects

to the Layer object. As Mapserver parses the mapfile, keywords indicate the start of a new map object. Three simple lines define the connection type, database connection string, and points Mapserver to the table geometry field.

Setting up the thematic symbology required a series of mapfile layer expressions. Some of these layers needed date input, which is not static information. These dates need to be updated. This was accomplished by passing variable definitions by the URL. For instance, ... &layer=incorpPlaces_status&presentDate=2010-07-03&mode=map... will instruct Mapserver to load the incorpPlaces_status layer and define the presentDate variable in the mapfile. In this example, all instances of %presentDate% in the mapfile will have the value of 2010-07-03. Figure 3 illustrates incorpPlaces_status layer. This layer uses three Expressions - all using the presentDate variable.

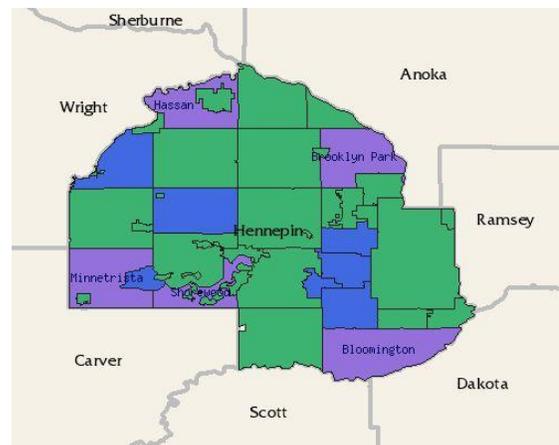


Figure 3. Mapserver produced image displaying the project Status map. This thematic map represents Complete (green), In Progress (purple), and Planned (blue) tasks for the scope of the project.

Website Development

The next phase was development of the website. The dashboard style project management site was designed with the WMS image as the focal point. Controls

were setup to display different views including: 1) active tasks, which tasks are currently being worked on and color coded schedule status (on time/ running behind, 2) status, which is viewing tasks in a done/not done perspective and, 3) resources, which tasks are assigned to a particular resource.

The backbone of the web application is the PostgreSQL database. This web solution interacts with the database in two distinct ways. First, maps are generated by passing values to Mapserver through URLs, which call Mapserver to read the database, interpret, and produce a WMS that is displayed on the site. Second, any non-map related outputs are populated by directly connecting to the database and returning the queried results (Figure 4).

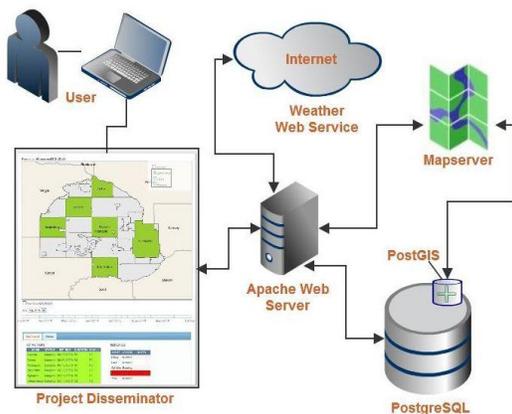


Figure 4. This network diagram shows the Project Disseminator data infrastructure.

Three tables were setup to provide further diffusion of the project management information. These tables were created by passing SQL commands through Npgsql and displaying the returned data in a table. The Active Tasks table displays the current tasks, status, estimated end date, duration, and the number of dates to planned completion. A resource table is used to display a snapshot of the resources assigned to the project. Information

includes: name of the resource, its' current status (example: "running" or "down"), and any notes that are relevant to the resources status, such as a brief description of an issue (i.e. technical glitches). Figure 5 displays the dashboard. The third table is the Task table, which displays a user defined resource(s), and lists their assigned tasks, sequence, estimated duration, planned and actual end, and status (complete, started, or planned). Figure 6 illustrates the task table with the resource map displayed.

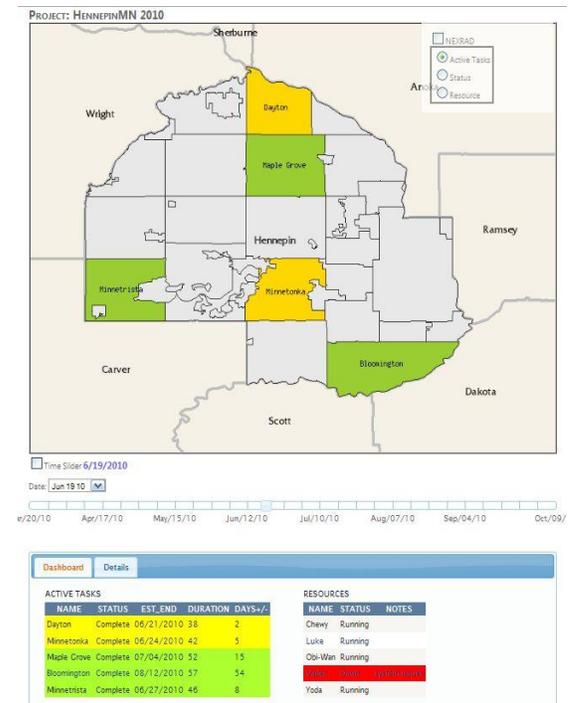


Figure 5. The Project Disseminator shows the Active Task (AT) map, AT table, and Resource table, which act as a monitoring tool. Notice the green and yellow in the map and AT table. As a task is coming within a week of the expected end date, the map and table will turn yellow. This color change serves as a visual cue to ensure intervention is not necessary.

Analysis Method

Wiggins (2007) concludes the only way to verify heuristic assumptions when redesigning a website is user testing and

web analytics. According to Wiggins, User Testing and Web Analytics are the only two ways to determine if the changes made on a website were successful. The Web Analytics Wiggins refers to involves web traffic mining.

Because the Project Disseminator website is just reading a sample project dataset, there are no stakeholders currently accessing the site. Therefore, this analysis solely focuses on User Testing through User Experience Analysis, as it is important to render its effectiveness in terms of “is the design doing what it is supposed to do for the user.”

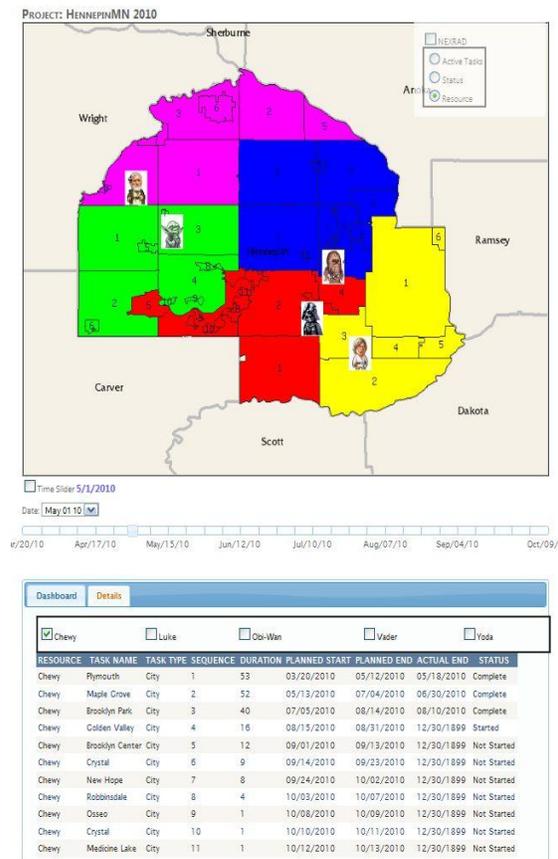


Figure 6. This screen shot of the Project Disseminator shows the Resource map and the Task table. This map also includes icon points representing the location of the resources. Monitoring projects with timely information and convenient tools allows for effective project control.

User Experience Analysis is an effective method for analyzing software and is commonly used among businesses to decide whether or not development efforts were successful. By quantifying the user experience, the end-user is the focal point and subjectivity is removed.

For the purpose of this case study, the User Experience Analysis focuses on three specific elements: usability, functionality, and content. Each of these elements on their own does not necessarily create a positive user experience; however when these factors are considered together as a whole, the success of the software design can be better assessed from the end-user perspective (Figure 7).

User Experience Analysis - Measured Elements

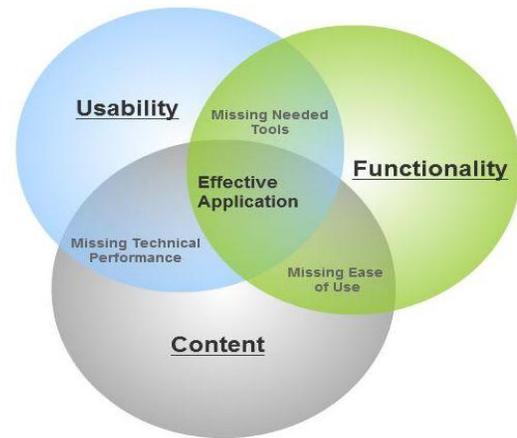


Figure 7. This graphic illustrates how the three User Experience Analysis elements are needed to satisfy good application design. If an element is lacking, the application will be missing a user’s need.

Within the three general elements, questions were created specifically to elicit user feedback. These questions were administered using the survey tool Zommerang. Zommerang is a software-as-a-service website that administers and aggregates survey information.

The analysis was broken into three sections, one for each of the three

elements of the user experience. For each of these elements, a series of statements or parameters against which the Project Disseminator website will be measured. For each question, users selected from four different rating categories: poor, fair, good, or excellent. In addition, users were encouraged to add comments for each of their answers thus providing additional qualitative data.

The survey population consisted of a sample of the target audience. The beta testing surveyed five interviewees, who all are subject matter experts of large scale GIS data collection efforts and project management. These professional end users provide prudent insight of general usefulness to specific bugs or needed tools/views. This type of feedback is necessary to understand the principles of evaluating software management tools.

Results

User Experience Analysis

For each analysis category (usability, content, and functionality), three to four questions were designed to specifically address each individual user experience component.

To provide guidance on composing the questions for the three evaluation components, working definitions were: 1) Functionality; defined by the technical processes that deliver services to the end user, 2) Usability; the general ease of use of web application features and components, 3) Content; referring to the substance and consideration of the components on the website (including: text, features, images).

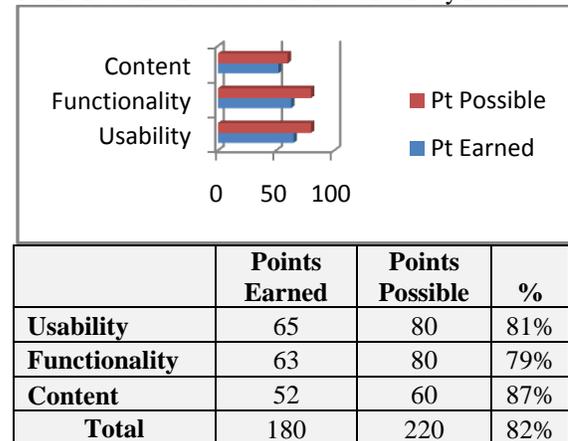
As mentioned above, the survey participants had four answer options (poor = 1, fair = 2, good = 3 and excellent = 4).

Points were assigned to each option and then a score was generated.

The user experience analysis question methodology was adopted and altered from content by Rubinoff (2010). To also help increase the validity of the data collection, the survey population was asked the same questions administered online through a web survey service. Users were instructed to answer the questions with the available options and to comment in question survey textboxes to further explain assessment.

The Project Disseminator web application received an overall average of 82% of the possible points. The strongest marks were in the Content section (Table 1).

Table 1. Consolidated overview of survey results.

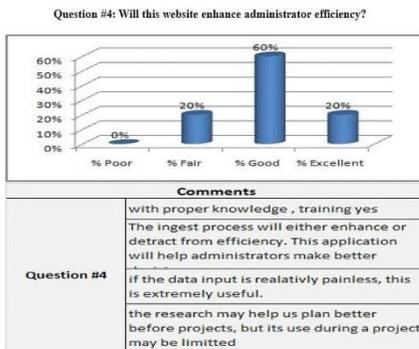
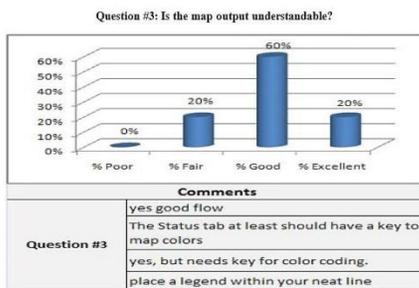
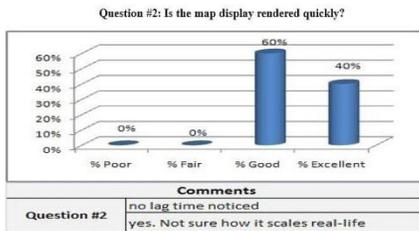
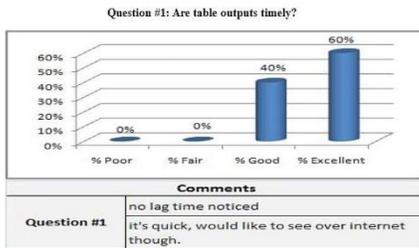


Question Breakdown

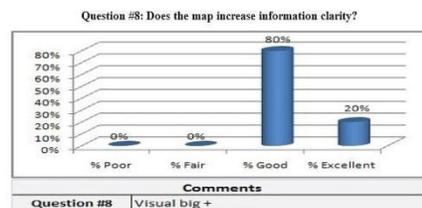
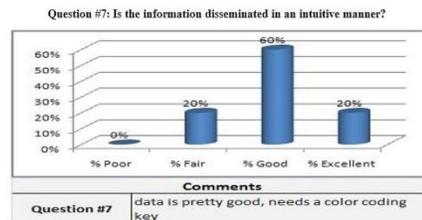
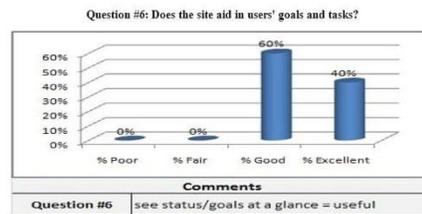
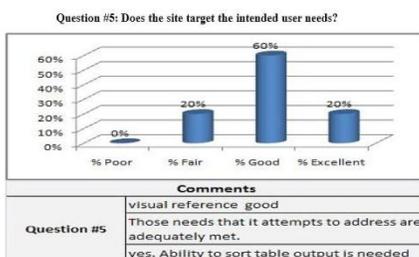
To explore variances of answers in the survey questions, each question was broken down to gain specific feedback. The questions, answer response, and user comments are contained below (Figure 8).

The two most common feedback suggestions included subjective input to further explore a need for legends in the maps and that the visualization method of communicating the information was useful.

Functionality



Usability



Content

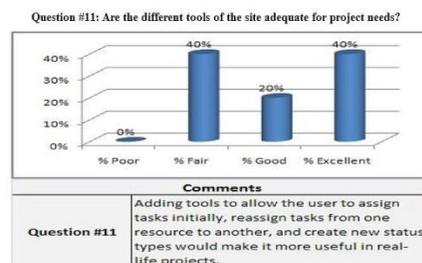
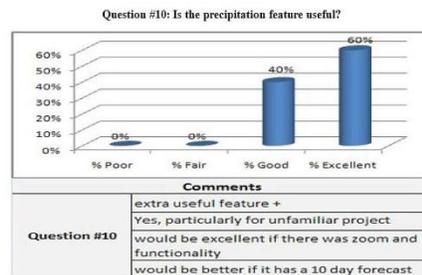
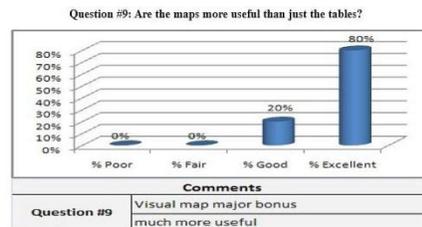


Figure 8. The user experience survey question breakdown. The graphic above shows the questions, answer variance, and the interviewee comments.

Question Breakdown Summary

There was general consensus on all but one question, #11. The results of this survey question showed the greatest variance in answers (Fair= 40%, Good= 20%, Excellent= 40%). This is an interesting result and supports the belief that personal preferences among project management tools can vary significantly from one user to the next, thus affecting the overall user experience.

Discussion

The scores for this evaluation were strong, especially due to the fact that the Project Disseminator is a prototype. The results of the User Experience Analysis provided constructive criticism. The main goal of the survey was not buttressing the applications pros, but rather to find aspects in need of improvement. With this information changes can be made to improve usability, functionality, and content.

Of the three measured components, functionality scored the lowest. This section received the highest number of “fair” ratings. As mentioned in the Results section, users’ answers and comments indicated a strong need for a legend to help identify color codes.

Also, although this application was solely designed to disseminate project management information, the users were thinking about how this information was going to be collected and edited. These necessary process concerns are valid but outside the scope of this project. Currently the application tables and maps only read the database. Further development will provide the application read/write capability.

Question #10 was evaluating the effectiveness of the precipitation

visualization tool. This application feature was designed to visualize the precipitation radar for project areas. One of the user comments received specifically addressed the need for a 10 day forecast. The National Weather Service freely provides data feeds in XML format so the future modifications of the application could include this functionality.

Another user comment addressed the navigation inability of the map. The WMS used to deliver the map is currently in “map” mode, which does not allow common web mapping browsing tools; such as zoom and pan. These abilities were not necessary for this prototype and were not added. The future course of action is using OpenLayers to add navigation functions and access to Google Map or Microsoft’s Bing Maps APIs. OpenLayers is open-source JavaScript library, which is actively involved with the Open Source Geospatial Foundation.

The largest limitation of the User Experience Analysis lies with the limited number of users that completed the survey. Because this is web GIS PM tool is a prototype, collecting feedback from a smaller selective sample few of subject matter was sufficient to evaluate and gain improvement points for the application to be modified and then subjected to a large population for further evaluation and testing.

Conclusions

Project managers use a wide array of tools, techniques, and software applications to help accomplish their team’s goal: a deliverable which meets all requirements, including timelines and budget. Projects that have a spatial aspect can be managed better by utilizing GIS.

Because of the advancement of open-source resources and web 2.0 style

data sharing, powerful in-house web GIS PM tools can be developed for the specific needs of the organization or project with the only input cost of development time.

Having a web-based information system, instead of a desktop data silo, is a necessary architecture design to permit timely information dissemination. By consolidating project data and sharing information from one source, project stakeholders can be ensured the project information they are viewing through the web PM application is accurate and timely.

A method of gauging application effectiveness is a User Experience Analysis survey. Feedback provided through this type of investigation allows the developer to change and add features that are backed by end users observations and comments.

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